

PHILOSOPHICAL  
AND  
MATHEMATICAL REASONS,

Humbly offer'd to the Consideration of the

PUBLICK:

To prove that the Present Works, executing at *Chester*,  
to recover and preserve the Navigation of the

RIVER DEE

Must intirely Destroy the same.

24

WITH SOME  
REMARKS on Mr. BADESLADE'S  
REASONS, &c. thereon.

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By their most Humble Servant,

JOHN GRUNDY

Of *Congestone*, in the County of *Leicester*,  
Land-Surveyor, and Teacher of the MATHEMATICS.

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L O N D O N:

Printed for the AUTHOR.

MDCCXXXVI.





T H E

P R E F A C E.

**B**EFORE I shall begin to make any Remarks (from the ocular Survey that I took) of the Navigation at Chester, it may not be amiss by way of Preface to sum up all such Qualifications, that each Man ought to be Master of, that pretends to make such Rivers Navigable that are acted upon by Tides coming up them; in order to prevent Noblemen and Gentlemen from being impos'd upon, so as to spend great Sums of Money to no purpose.

First, Every Man that hath the Direction of such Works, ought to be a good Mathematician, not only in the Theory but Practice, by which Knowledge he will be capable of forming such Propositions and Theorems that will be found wanting before he begins his Works; as taking his own Surveys, and Drawing such accurate Maps as ought to be made of such open Bays, Rivers, Creeks, and Outfalls, &c. By such an actual Survey (taken by himself) he will have a thorough and superior Knowledge of every part of his Undertaking; and in the next place he ought to be capable of taking the Levels of each part of the Surface of his Lands or Sands, and the Bottoms of such Rivers, Channels, Drains, or Creeks, that are within his Survey, by such nice Instruments, and in such an accurate manner, that all his Operations may be mathematically Demonstrated to be Truth itself before the nicest Examiner.

Secondly, He ought to understand natural Philosophy, in order to make his Enquiries just, with regard to the Laws of Motion, the Nature, and Action of the Tides upon different Rivers, Channels, Outfalls, and Seas, that by knowing their Action, he may be enabled to find out

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such

*such proper Re-actions as will be found wanting to keep the Channels or Outfalls in such a good State, as to serve all the Ends requir'd, or to shew the impossibility of such Works being brought to Perfection before any more Money is expended than what pays for such Enquiries.*

*Thirdly, By such Knowledge he will be capable of accounting for the Fall of Rains, the Force of Back Waters, or Freshes in the greatest Extreams, the Capacities of Sluices, or new Cutts to discharge any given Quantity of Water in any given Time, the Pressure any Sluice, or Bank wheresoever placed must sustain. And by the help of such Calculations, make Sluices of such a Strength, and Banks of such a Capacity, as they shall not be blown up or broke down. He will be farther capable to find out what Opening and Capacities new Cutts ought to have next to their Outfalls, to receive the Tides at their putting in, with the least Friction; and how to proportion them to the acting Force of the Tides.*

*Lastly, He ought to be capable of inventing such Engines, and calculating their Force, and Motion, that will be found wanting in the executing of such Works. To understand the Nature of falling of heavy Bodies in perpendicular Directions, as well as how they will be accelerated by falling along Plains of different Inclinations; to understand the Phænomena of Fluids with regard to their Pressure at different Heights, the Laws of running of Rivers, to find out their Velocity, and to account for their Friction, according to their different Inclinations or Irregularities. Then the Consequence must be, that an Undertaker, so qualify'd, will be capable of giving in his Proposals with Certainty and Judgment, of what ought to be done to drain Lands, or make Rivers Navigable, and to calculate the Expence requir'd to perform the same, or with the same Certainty and Judgment to demonstrate the impossibility of such Works being brought to perfection. And what can be the reason, but the want of being so qualified, that so many different Opinions of Engineers upon the same Subject are generally propos'd, when in Fact there can be but one best general Theory or Foundation of draining Lands, or making the same River Navigable.*



C H E S T E R  
N A V I G A T I O N  
C O N S I D E R ' D ;  
W I T H S O M E  
R E M A R K S  
O N  
M r . B A D E S L A D E ' S R E A S O N S , & c .  
t h e r e o n .

Humbly presented to the P U B L I C K .

**I**N *May*, 1735, I view'd the Works carrying on at *Chester*, under the pretence of making better the Navigation of the River *Dee*, from that antient and honourable City to the Sea. And was very much surpriz'd to find them so far from being calculated to improve; that they seem'd in my humble Opinion plainly to tend to destroy the Navigation, and to cut off all Communication  
to

to and with the Sea from *Chester*, if the Works said to be propos'd were carried into execution.

I told some Gentlemen my Opinion of the Works then made, and also of what I could learn was design'd to be done, which I afterwards deliver'd in Writing to the following Effect, *viz.* that the *new Canal* was cut through much too high a Soil; that it was made very improper as to its Capacity; that the Laws of Motion and Percussion will evidently prove its Course or Direction to be very irregular and disadvantageous, as well with Respect to its receiving and conveying the Land-Floods as the Tides: And that it wou'd be very difficult, if not impossible to gain any Way or Passage to the Sea, which wou'd not be silted and choak'd up at the Mouth of it against all the Force that could be gained from the back Waters. In short, the whole Undertaking seems to be carried on, not only against Sir *Isaac Newton's* Theory of the Tides, but against all the common and receiv'd Rules in Practice, and daily Use in Mechanicks and Mathematicks, as well as against, and directly contrary to other Rules plainly and justly deducible in Theory therefrom, and confirm'd by Experiments; and quite against and contrary to Nature.

BY what is said in the Preface, I humbly conceive, that every Lover of, and impartial Inquirer after Truth, will allow that the very Foundation of making Rivers Navigable, of restoring a lost, or improving a bad or indifferent Navigation, and of draining Lands, depends upon the Knowledge of natural Philosophy and Mathematicks, in all its Branches, and that the Undertaker of such sort of Works ought to be a good practical Surveyor, and able to take his own Levels, and to draw his own Maps. Without these Qualifications, (and the more they are improv'd by Observation and Experience, the better) I apprehend it exceeding difficult, if not impossible for an Undertaker in Affairs of these Natures, to succeed in such complicated Works, whose Usefulness or Defectiveness will be in proportion to the Degree of his Improvement and Skill.

THE Duty and Respect I owe to every Man, requires, that I pay that Regard to Mr. *Badeslade*, which his Merit deserves. I have not the Honour to be known to that Gentleman, but in justice to him, I think myself obliged to acknowledge, that the Publick is much indebted to him for the judicious Remarks he has publish'd on the Subject of Navigation and Draining, which I freely confess are in my little Apprehension the best yet extant. But with the greatest  
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Deference to his Judgment, I must beg leave to shew, that I believe he is misinform'd in some Circumstances relating to *Deeping-Fenn*, and the River *Welland*; and that there is a Possibility, the Instances, which that ingenious Gentleman brings as Parallel to *Chester*, may not in reality be altogether such. For I cannot but be of Opinion, that no Man can tell, whether this, that, or the other Place is parallel to another, or say how far they are parallel, unless he draws the Maps and takes the Levels of the Places propos'd to be compar'd. It must be own'd, that particular Circumstances may make a wide Difference; and that these Circumstances and Differences cannot I humbly conceive be found out, or known by any other Art or Method than that of Mapping and Levelling, from whence alone Facts can be stated, Contents and Capacities judged of, and proper Works projected for Execution, according to the Facts, Falls, and Circumstances of the particular Place.

CAN Length, Width, Depth, Height and Capacities be known or judged of with any Degree of Certainty without Mensuration and Calculations therefrom? Surely no: I therefore lay it down for a Rule, that no body can make the truest Judgment (human Affairs are capable of) in any Case of Navigation or Draining, or so good and certain a one without taking of Levels and Drawing of Maps, as with it; nor can any Artist tell wherein any complicated Work is Defective, or shew the Occasion of the Defects, unless he has his Information from just Maps and Levels. This therefore in my humble Opinion is so absolutely necessary to be first done, that a Superstructure cannot be justly or with certainty rais'd without it.

IN the Years 1731, 2, 3 and 4, I was employ'd in and near *Spalding* in *Lincolnshire*, not only to survey Land, but to draw Maps, and take the Levels, in order, as well to drain, as to make better or improve the Navigation (which was very bad and almost lost) of the River *Welland*. By the orders of the Adventurers in *Deeping-Fenn* I drew a Map of that River in 1734. of about twenty two Miles in Length, and took the Levels thereof in upwards of two thousand five hundred different Places or Stations, to a little below *Fosdyke-Wash-House*, and from thence I went in Boats down to the Scalp.

Mr. *Badeflade* in his Reasons, &c. lately printed at *Chester*, p. 5. says, "Water requires at least six Inches in one Mile's Descent to flow or move at all. And in page 9, he says, that about the Year 1730, Capt. *Perry* undertook to drain that Country, by Sluces  
" set

“ set down cross the *River* above *Spalding*, to hold up between the  
 “ *Banks* of the *River* the *fresh Waters* to a considerable Height,  
 “ and to take in and hold up high *Spring Tides*, (for ordinary *Tides*  
 “ cou’d not reach him) and to let the *Scour* off, when the *Tide* was  
 “ ebb’d out of the *River*. The *Proprietors* had great *Expectations*,  
 “ but when the *Scour* was let off, it only pool’d a Depth near the  
 “ *Sluice*, and threw up a Barr of Sand a little beyond; and though  
 “ the Captain us’d *Porcupines* and other Devices to move the *Sand*,  
 “ yet it subsided again at a sma’ Distance, and cou’d not be driven  
 “ out to *Sea* by the Force of his *Scour*, though the *River* is narrow,  
 “ and but seven Miles long from the *Sluice* to the *Sea*.

I have drawn up at the End of these Remarks two Propositions,  
 one to prove that Water will move along a River or Canal that hath  
 but four Inches Fall in each Mile, and the other to prove no Level  
 can be taken betwixt two distant Places in any Channel by the diffe-  
 rent Height of the same Tide at those two Places, to which I beg  
 leave to refer my Reader.

IN the Year 1734, and in *April* 1735, I found the following  
 Facts upon the *River Welland*, and the Channel a little below the  
 Wash-House aforesaid. From Capt. *Perry’s* Sluice thither, is up-  
 wards of nine Miles and a half, and the Floor of that Sluice was higher  
 by twenty-two Inches than the Bottom of the Channel there, from  
 an Horizontal Plain. Where the Inclination of the Bottom of the  
 River three Miles below, that Sluice was but two Inches and a half,  
 I there found, when the Doors of the Sluice were drawn up, and  
*Cowbit-Wash* pretty full, (above the Sluice) the Velocity of the  
 Stream to be 140 Feet in one Minute. I found no Barr of Sand  
 nearer than upwards of three Miles below this Sluice, nor any Depth  
 of Water pool’d near the said Sluice, or deeper than the Floor or  
 Bottom of it, except where it was dug out with Spades by Capt. *Perry’s*  
 Orders. An ordinary Spring-Tide Mr. *Badeflade* admits does not reach  
 the Sluice; yet the Navigation was worse before it was set down,  
 than it has been since. The Sluice therefore seems for the above Rea-  
 sons to have been in some Degree useful and of Advantage.

IF as Mr. *Badeflade* has remark’d, there is sixty Foot Fall from  
*Chester* to the Sea, and if there is not two Foot Fall from Capt.  
*Perry’s* Sluice to the Channel aforesaid, then by considering the Na-  
 ture of Bodies rolling along different inclin’d Plains; we may con-  
 clude, that in this Circumstance, the parallel Case between *Chester*  
 and

*Spalding* is as 60 to 2, then there is the same Difference between the same Scheme, if suppos'd to be executed at both Places.

THE same Reasoning I apprehend will hold good in any other Place, making Allowance for the Length and Inclination of their different Plains to Sea, and the different Inclinations of the Lands on each side the Bay.

Mr. *Badeslade* says in page 6. That after *Saltney-Marsh* is embank'd, and the *white Sands* are gain'd from the *Sea*, not only the *Navigation* will be lost, but also the *Low-Lands* above *Chester*, adjacent to the River *Dee*—And again in page 8.—Therefore when the *Salt-Marshes* and *white Sands* belonging to *Chester River* are embank'd, of necessity *Hyle-Lake* and the *Barr* must grow up and the *Navigation* be destroy'd for want of a sufficient *Flow* and *Reflow* of the *Tide-Water* to keep 'em open, in like Manner, as did the *Outfall of Rye*.

I don't rightly apprehend this Gentleman's meaning, there's a Possibility, as I have said above, that the Instances we apprehend to be Parallel, may not be so in Fact, and that *Circumstances* may make a wide Difference. At present I am of Opinion (which I can't rectify without Surveying and Levelling the whole) that all the Lands and Sands above *Weppraw-Gutter* may be made good Lands without any Prejudice to the *Navigation*, or to the draining the adjacent Lands. And that the imbanking *Salt-Marshes* in some Degree, is so far from being prejudicial, that it is of the highest Advantage to both, and quite agreeable to all receiv'd Principles in *Hydrostaticks* and *Mechanicks*, as well as to the constant Laws of Motion: for where the Inclination of the Plain is the same, it will surely be allow'd, that a large and deep Channel, whose Capacity is found by Calculation to be justly proportion'd, and fit to receive all such Waters as must Flow and Reflow thro' it, has a greater Momentum to remove any Obstruction, than the large disproportion'd and widely extended shallow Channel.

I appeal to the most Judicious of those, who have been, or are the best acquainted with the *Chester Channel*, whether if such a Channel might (by any Art) be gain'd, as wou'd be found sufficient to receive all the Waters that must Flow and Reflow thro' it in a common Spring-Tide, where there is the greatest Fall, as far as *Burton-Head*; and if the Causeway at *Chester-Bridge* was taken away, in order to give the Tides the greater Liberty to flow up the River, their *Navigation* might not be improv'd thereby to the greatest Perfection it is now capable of.

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THEN

THEN consequently if so, the remaining Sands as far as *Burton-Head* above the Capacity of such a Channel, might be bank'd in, and made good Land, without any Prejudice to the Navigation.

I entirely agree with Mr. *Badeslade*, " That no Man's single Judgment ought to be taken, and no Scheme of this publick Nature ought to be executed without the general Approbation of the best Judges." And I crave leave to add, a proper Scheme shall be produced, whenever the Publick shall require it of their

*Most Humble and most Obedient Servant,*

JOHN GRUNDY.

### PROPOSITION I. (Fig. I.)

Suppose ABCDEFG, to be a Reservoir of Water, and that from the said Reservoir there be made the Canal MNRW, whose Inclination with regard to the Horizontal Line *ab* is four Inches Fall in each Mile, and that the Length of the said Canal to its Outfall at NW, is six Miles. Let us suppose BDFG to be a Sluice, and another to be plac'd at NW; now, if we suppose the said Reservoir full of Water up to the Surface ABCD, and likewise the Canal up to the Surface QN; *Quære*, If the Sluice BDFG, and that at NW be both drawn up above their respective Surfaces of Water, will the said Water have any Motion at all along the said Canal?

THIS Proposition needs no Demonstration, because from Experience it is now become a receiv'd Truth amongst most modern Engineers, that Water will run along any River, whose Inclination is not above four Inches, or four Inches and a half Fall in one Mile: but to prove from self-evident Truths it must be so, it may not be amiss to give the following Demonstration.

WHILST the Water in the said Reservoir and Canal are in a state of Rest, it is self-evident from the Laws of Gravity, that their Surfaces must be plain and parallel to the Horizon, or rather a Segment of a Sphere concentrical with the Earth. For as the Particles of Water are suppos'd to yield to any Force impress'd, they will be mov'd by the Action of Gravity, till such time as none of them can descend any lower. When this Situation is once attain'd, the Fluid must remain at rest, (unless put in Motion by some foreign Cause,) because none of the Particles can now move without ascending, contrary to their natural Tendency.

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*Secondly*, Whilst the Particle  $i$  is at rest, it is manifest from the Laws of Hydrostaticks, it must be press'd upon equally on all Sides by such other Particles which surround it: for if it was not so, it must yield to the stronger Force so long, till it is equally press'd every where; and when it is equally press'd on all Sides, (as it must be when at rest) it is plain, from the third Law of Nature, that it must have a Re-action so great, as to equally press whatever is contiguous to it, in all manner of contrary Directions. Then consequently the Force by which any Particle of Water, that is at rest, presseth against any like Particle that is contiguous to it, must be equal to the Weight of the incumbent Column of Water above it: therefore the Pressure it must sustain in itself from any other part, or according to any other Direction, must likewise be equal to the Weight of the same incumbent Column; and since Action and Re-action are equal, we may from thence conclude, that the Particle  $i$  must press in all manner of Directions with the same Force that is equivalent to the Weights of its incumbent Column  $ia$ .

NOW if the Sluice at NW, and B D F G be both drawn up, it is plain by Construction, as well as the aforesaid Laws of Gravity, that the particle  $i$  will descend to  $k$ ; and there its Pressure to move forwards will be in proportion greater than when at  $i$ , as  $bk$  is greater than  $ai$ . By the same way of reasoning the Particle at S, will descend into its Outfall, and make way for the Particles  $q, p, n, m, l$ , to follow it; and then the consequence must be, that the whole Column of Water in the Canal must be put in motion, and continue to move, (if there be but the least Descent imaginable) so long as there is Water to supply it from the said Reservoir at the Head. Which may be further prov'd from mechanical Principles. Thus; the Particle at  $k$  being in motion, will be continually accelerating, and will be so much greater at  $l$ , as a Body in falling from  $c$  to  $l$  would be accelerated more than it would be in falling from  $b$  to  $k$ ; by the same Laws it must move to  $m, n, p, q, S$ , and so into its Outfall. It is farther evident from Hydrostatical Principles, that the Velocity of the Water in the said Canal, will be greater, or smaller; and that in proportion to the different Heights of the Water in the said Reservoir and Canal. Again, if we suppose the River or Drain V, to supply the said Reservoir with Water from some greater Inclination, than that of the said Canal, which is generally the Case, where Wa-

ters are convey'd by Rivers or Drains through flat and fenny Countries to their Outfalls. The Water in the Canal MNRW will have its Velocity (in proportion to the Inclination of the River V) increas'd, tho' the said Canal hath no greater Inclination than four Inches in each Mile.

### PROPOSITION II.

TO prove that the Difference betwixt the rising of the same Tide at any two different parts as H and F, in any open Bay, or Channel, cannot give the just Inclination of the Plain betwixt those two Places.

### PREPARATION. (See Fig. II.)

LET ADHF represent a Section of any Channel where the Tides put in, (as suppose the Channel between *Chester* and *Wild Road*.) Let ADGE represent the Surface, and *m, n, p, q, W, V, X, T, O,* the Low-Water Marks; let *m* represent *Chester-Bridge*, and *o* *Wild-Road*; AC is the Horizontal Line, drawn from the Surface of High-Water at *Chester-Bridge*, HF represents the Bottom of the Channel, and AB the just Inclination up the Channel the Tide must have, before it can move to A.

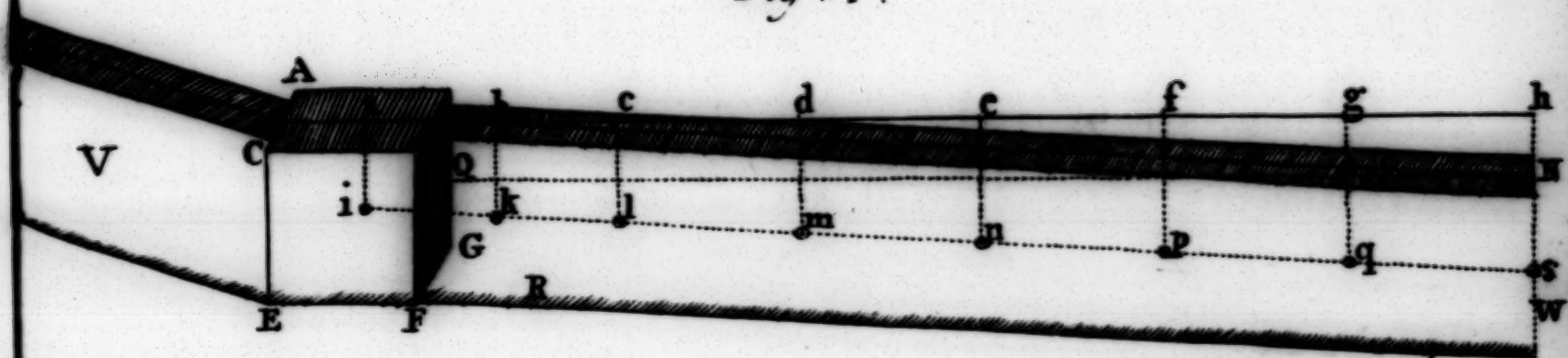
### DEMONSTRATION.

BY the first Proposition it is prov'd, that the Surfaces of Waters are not in an Horizontal Plain, except such Waters are entirely at rest, without any Motion at all. Then consequently any River or Channel in motion cannot have its Surface in an Horizontal Plain, but must vary from that, in proportion as its Velocity is swifter or slower, or as its perpendicular Pressure is increas'd or diminish'd.

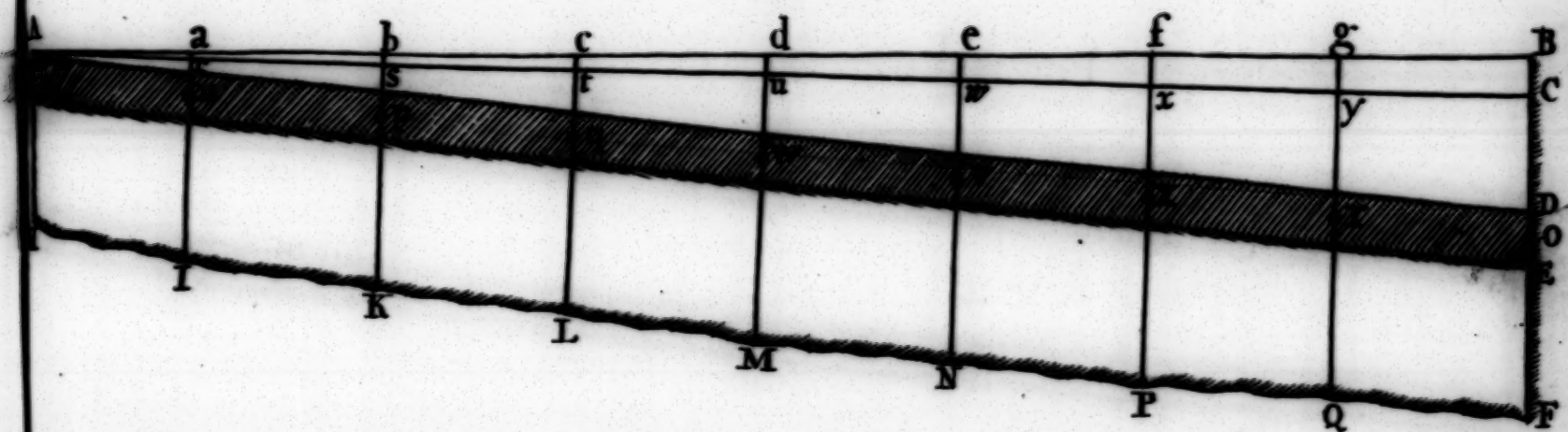
WE may further learn from the Nature of the Tides, that at their putting into any Channel, the Water is rais'd above its ordinary Level, by being made considerably lighter in its specific Gravity, by the joint Attraction of the Moon and Sun (in Spring-Tides;) therefore the Consequence must be, that the Water will be rais'd to B, before it can move forwards, up the River to A: For it is plain from the Laws of Motion, (in fluid as well as solid Bodies) that the Water at the putting in of the Tides, must rise so high, as to make its Inclination up the Channel in the Direction of BA, before it can overcome the Re-action of the Water in the Channel in its natural Course, to cause it to move up along with it towards its Head.

FROM

*Fig. 1.*



*Fig. 2.*



FROM what hath been said it appears very plain, that the Water must rise above the Horizontal AC to B, before it can make its Perambulation up the Channel to A; so that its whole Rise during such a Tide, must be from O to B, from T to G, from X to F, from V to e, &c. and not from O to c, from T to y, from X to x, from v to w, &c. as by some hath been imagin'd.

THEREFORE all those that take it for granted, that the Difference of the Rise of the same Tide at any two separate Places of a Channel, gives the just Inclination of the Plain between these two observ'd Points, must vary so much from the just Inclination of the said Plain as the Line OB is greater than OC; then consequently, if the taking of the Levels are grounded upon false Principles, the rest of the Proceedings must be so too, and cannot succeed in practice but by meer Accident.

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# P R O P O S A L S

For Printing by SUBSCRIPTION,

A New Method, grounded upon *Philosophical Experiments*, and *Mathematical Calculations*, for Draining all sort of *Low-Lands*; the *making, restoring, and improving* Navigation in *Inland Rivers*, as well as such *Channels*, that are in open *Bays* or *Harbours*, where Tides put in: Except in such *Cases*, where it is impossible to compleat the same.

By JOHN GRUNDY,

Of Congestone, in the County of *Leicester*, Land-Surveyor  
and Teacher of the Mathematics.

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This Treatise is divided into the following Parts.

I. **B**Y way of Introduction is collected all such Schemes that fell into my Hands, propos'd by different Persons, with Philosophical and Mathematical Remarks upon each Scheme.

II.

II. A new Method (practis'd by myself) of drawing of Maps, and taking the Levels of open Bays, Rivers, Drains, and such low Lands as want draining; which said Method is there prov'd by Experiments, and Mathematical Demonstrations, to be the very Foundation of draining all low Lands, and making Rivers navigable.

III. The Phænomena of the Tides, from the Laws of Motion, how they act upon open Bays and Rivers, as well as different Seas.

IV. All such Mechanical and Hydrostatical Propositions, that are necessary to be known in draining, and making Rivers navigable.

V. From Philosophical Experiments, and Mathematical Calculations, Propositions are rais'd, and Theorems drawn, how Canals, Drains, and new Cuts ought to be made, or old ones repair'd, to convey such Waters as must flow thro' them in a given time; how Banks ought to be made or repair'd of any Manner of Strata of Earth, from the strongest Water-Clay to the lightest Sand, so as to resist any given Pressure; and how to find out the Pressure any Bank must sustain, wheresoever plac'd; how Sluices and Tunnels ought to be plac'd, and to find their just Capacities to discharge any given Quantity of Water in any given time; in what degree Salt-Marshes ought to be bank'd in, in any open Bay, to improve their Navigation, instead of being a prejudice to it; how Reservoirs or artificial Scowers ought to be made, and plac'd to act with the greatest Force for to scower away the Sands in any open Bay; how Locks ought to be plac'd upon navigable Rivers, with proper Directions for making Inland (as well as such Rivers or Channels that are acted upon by Tides coming up them) navigable; and likewise the best Methods for restoring lost Navigation.

VI. A Proposition to shew in what Direction petit Drains ought to empty themselves into the Rivers or main Drains, for the better draining such Lands whose Waters they discharge.

VII. The best manner of draining Boggs or Morasses in Inland Countries, either by open or cover'd Trenches fill'd with Older-Faggots, with some new Improvements in the binding and laying in of such Faggots, so as to convey such Waters they are to discharge into their main Drains in the least time; and how to find the greatest Falls where such Trenches or Drains ought to be cut thro', to drain in the best Manner.

VIII. Draughts and Explanations of all such Engines as are of the most use in the executing of such Works, with several Improvements of my own.

IX.

IX. The foregoing Propositions applied to practice, by a particular Scheme I drew up in the Year 1734, at the Desire of the Honourable Company of Adventurers belonging to *Deeping Great-Fenn*, to restore the Navigation of the River *Welland*, and Drain the said *Fenn*: The said *Scheme* was approv'd of, and is now in the Hands of the Adventurers, 'till Money can be rais'd to put it in Execution.

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## C O N D I T I O N S.

**T**HIS Treatise will contain about Sixty Sheets, in Quarto, of the same Letter and Paper with the printed Proposals, and near sixteen large Copper-Plates; and will be deliver'd to the *Subscribers* in Sheets, at ten Shillings a Book, half to be paid down at the time of Subscription, and the other half at the Delivery of the Book. The Manuscript being almost all fair writ out for the Press, will be printed off as soon as a competent Number of Subscriptions are taken in. And proper Places for the taking in of Subscriptions, will be advertis'd in the Publick News-Papers in a little Time.

F I N I S.

